

USE OF EXTENDED-RANGE PROGNOSSES FOR FIRE-WEATHER FORECASTING

FRANCIS D. BEERS

U.S. Weather Bureau, Portland, Oreg.

and

DEVER COLSON

U.S. Weather Bureau, Washington D.C.

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ABSTRACT

In order to make the regular extended forecasts more directly applicable to fire-weather forecasting problems, the 5-day circulation patterns are studied to determine possible relationships with relative humidity in northwestern Oregon and with thunderstorm occurrences in the northern Rockies. An objective forecast technique is developed for the September afternoon relative humidity in northwestern Oregon. The technique is based on the 5-day mean 700-mb. heights off the coast, the 5-day mean 700-mb. height gradients across the coast, and temperature anomalies for the period from 1949 through 1958. A similar objective forecast technique is developed for July and August thunderstorm occurrences in 10 National Forests in western Montana and northern Idaho. This technique is based on 5-day mean 700-mb. east-west and north-south height gradients and precipitation anomalies over the area for the period from 1954 through 1958.

Contingency tables are prepared and skill scores computed using the developmental observed data and the prognostic data for the same period. The forecasts for the 1959 fire season, which were used operationally, are evaluated.

1. INTRODUCTION

In practice, there has been rather limited application of the U.S. Weather Bureau's extended forecasts to local fire-weather forecasts. The primary prognostic charts are in terms of expected 5-day mean temperature and precipitation anomalies. These are not directly applicable to such weather elements as relative humidity, local winds, and lightning which are of extreme importance in fire control operations.

Probably the principal reason for the failure to apply these forecasts has been the lack of information on the relationships between the prognostic data available to the field forecaster and the weather elements important in fire-weather forecasting. Even to the experienced meteorologist, such relationships are neither simple nor readily obvious. Furthermore, if such relationships exist, they may vary greatly from one area to another due to differences in topography and distances from the various centers of action in the general circulation.

This study was undertaken to examine the feasibility of determining such relations for periods of low relative humidities in northwestern Oregon and for the occurrence of thunderstorms in the northern Rocky Mountain region.

2. RELATIVE HUMIDITY IN NORTHWESTERN OREGON

Periods of low relative humidity in northwestern Oregon during the month of September almost invariably

coincide with periods of strong east winds across the Cascades. Extended-period forecasting of this condition is extremely important in the control of fires and slash burning operations during this time of the year.

The data used in this study were for the month of September during the 10 years from 1949 through 1958. The daily 4:00 p.m. relative humidities for three representative stations in northwestern Oregon (Salem, Portland, and Eugene) were averaged over each of the 5 days coinciding with the dates of the extended forecasts. The 4 p.m. time was chosen since this is the time at which most fire-weather data are collected. This time corresponds closely to the time of the lowest humidity, strongest wind, and generally the most critical fire period.

The departure from normal charts very clearly point out significant changes in the mean circulation patterns [1]. The average departures from normal of the pressure-heights at the 700-mb. level that were observed for the period September 19–23, 1957, are shown in figure 1. The average 4:00 p.m. relative humidity over this 5-day period for northwestern Oregon (indicated by star in fig. 1) was 20.3 percent, the lowest of any of the 5-day periods in the 10 years of data. The important feature is the area of intense positive departure from normal in the eastern Gulf of Alaska. In the center of this area, the heights averaged 390 feet above normal. In other words, there was a tendency for an intense ridge to persist over this area during this period. This pattern was

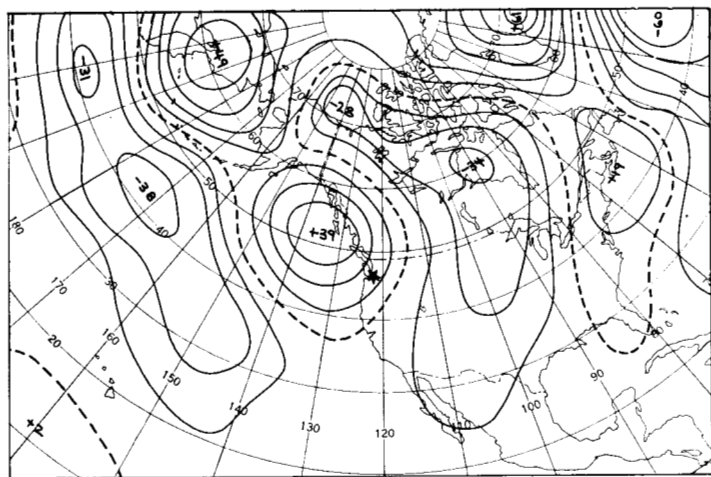


FIGURE 1.—5-day mean 700-mb. departure from normal height pattern for the period September 19–23, 1957. In this period the average 4 p.m. relative humidity over northwestern Oregon was extremely low, 20.5 percent.

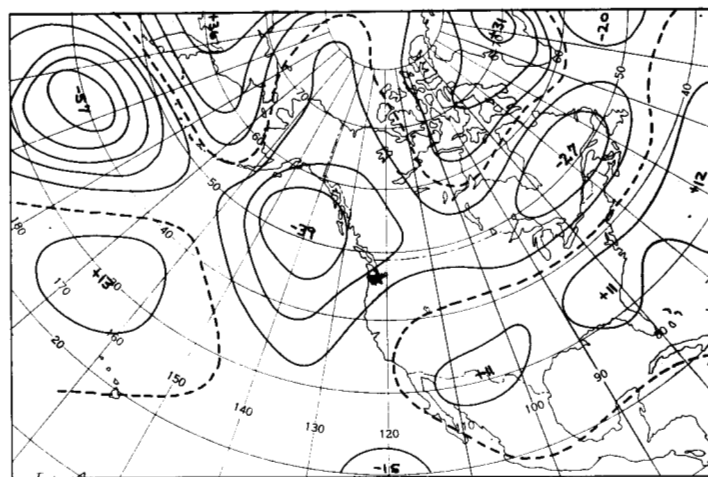


FIGURE 2.—5-day mean 700-mb. departure from normal height pattern for the period September 26–30, 1951. In this period the average 4 p.m. relative humidity over northwestern Oregon was extremely high, 64.4 percent.

typical of all the warm dry periods with strong east winds over northwestern Oregon.

The departures from normal of the 700-mb. heights for the period of September 26–30, 1951, are shown in figure 2. The average 4:00 p.m. relative humidity was 64.4 percent for this period, one of the more moist periods during the 10 years of data. This shows a strong negative departure from normal in the same general area as that of the positive departure in figure 1, which indicates the tendency for troughs of cool, moist air to persist over the Gulf of Alaska.

The presence of a positive departure from normal in the dry periods and a negative departure from normal in the wet periods was noted in nearly all of the 98 5-day periods during the 10 years. There was, however, considerable variation in the exact location and the magnitude of the departure from normal center in the different periods.

While the departure from normal charts are very convenient and useful in the study of the meteorological conditions associated with the wet and dry periods, these charts are not included along with the regular extended forecasts and are not readily available to the field forecaster. Therefore the information obtained from the study of the departure from normal charts was interpreted in terms of 5-day mean 700-mb. circulation charts. Many different 700-mb. heights, height gradients, and other variables were tried, but the best results were obtained using the parameters shown in figure 3. The vertical coordinate is the 700-mb. 5-day mean height value just off the coast (actually at 45° N., 125° W.). The horizontal coordinate is a measure of the pressure-height gradient between this point and the interior, actually the mean of the height gradients from 45° N., 125° W. to 50° N., 115° W. and from 45° N., 125° W. to 40° N., 120° W.

The numerical entries on the scatter diagram are the

average 5-day relative humidities at the three selected stations in northwestern Oregon. The entire set of 98 5-day periods represented on this scatter diagram were then divided into the five classes: A, B, C, D, and E with the average relative humidity increasing from A to E. One-quarter of all cases occurs in each of the three middle groups and one-eighth of the cases in each of the extreme classes.

A careful search was made for other parameters in the 5-day mean prognostic material sent to the field forecasters that would be useful in forecasting the relative humidities in northwestern Oregon. Many such parameters were tested and had to be abandoned because valid relationships could not be established. However, it was found that the observed 5-day temperature and precipitation anomalies for northwestern Oregon each had a good correlation with the relative humidity in that area. The temperature anomaly was selected, as it was felt that the forecasting skill for this feature is a little better than in the case of precipitation.

A new scatter diagram, shown in figure 4, combines the results from the circulation patterns and the temperature anomalies. The vertical coordinate includes the standard temperature anomaly classes: much above, above, normal, below normal, much below normal. The four intermediate classes, such as much above to above, were included because more than one anomaly class may be present over the area of northwestern Oregon. The horizontal coordinate in this scatter diagram comprises the humidity classes taken from the previous scatter diagram. A dividing line was drawn as shown in the figure to best separate the low and high relative humidity periods. This line corresponds to an average 5-day relative humidity of 40 percent. This division is a fairly practical one, since the closing down of many operations and certain insurance regulations are based on a critical relative humidity of 30

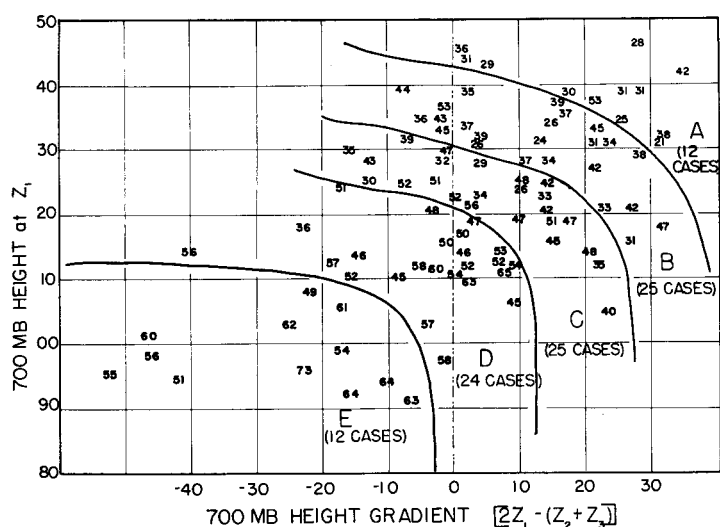


FIGURE 3.—Scatter diagram showing 5-day average 4 p.m. relative humidities for northwestern Oregon in relation to 5-day mean 700-mb. heights and an average 5-day mean 700-mb. height gradient.

percent. Any 5-day period with an average of 40 percent will usually have some days with 30 percent or lower.

Using the two graphs (figs. 3 and 4) with the 10 years of observed 5-day mean 700-mb. height, height gradient, and temperature anomaly data, the contingency table shown in table 1A was constructed. Actual 5-day average relative humidities at the same three selected stations of less than 40 percent verified the dry period forecasts and 40 percent or more verified the moist period forecasts.

TABLE 1.—Contingency table for dry and moist 5-day periods for September

A. Using 5-day mean maps, 1949–58

		Expected		
		Dry	Moist	Total
Observed	Dry.....	27	10	37
	Moist.....	12	49	61
	Total.....	39	59	76/98

Skill score=0.53

B. Using prognostic 5-day mean maps 1949–58

		Expected		
		Dry	Moist	Total
Observed	Dry.....	23	13	36
	Moist.....	19	42	61
	Total.....	42	55	65/97

Skill score=0.32

C. Using prognostic 5-day mean maps 1954–58

		Expected		
		Dry	Moist	Total
Observed	Dry.....	13	6	19
	Moist.....	9	28	37
	Total.....	22	34	41/56

Skill score=0.42

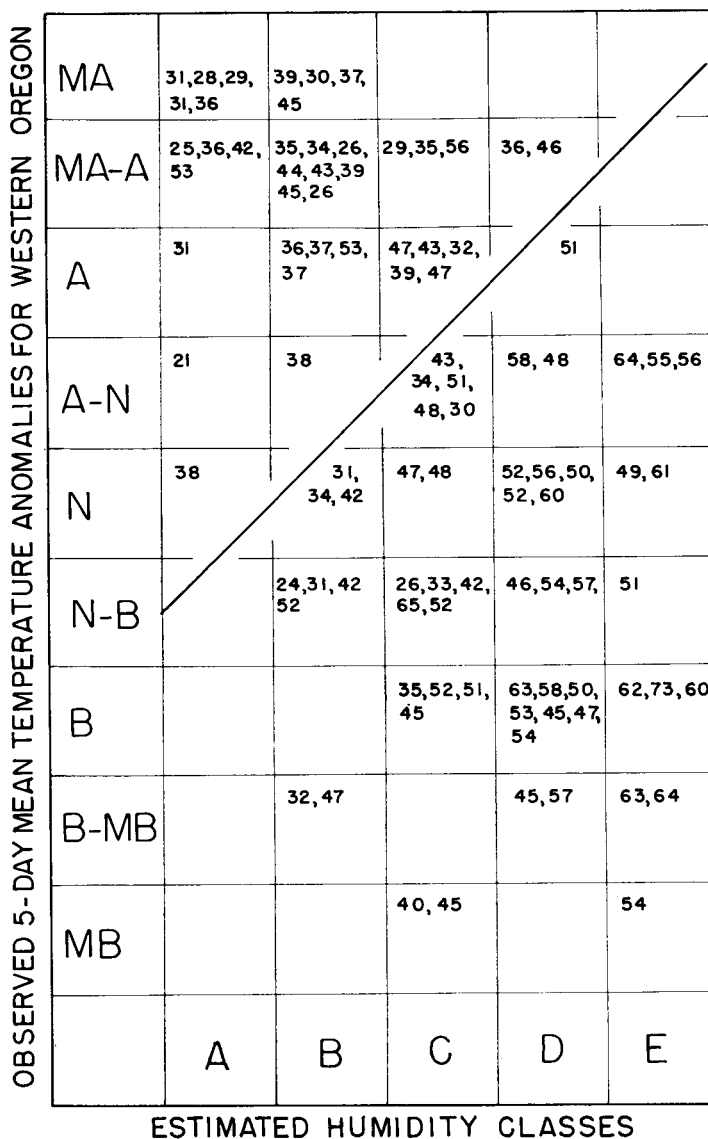


FIGURE 4.—Scatter diagram for the 5-day average 4 p.m. relative humidities for northwestern Oregon. Abscissa is the estimated humidity class from figure 3 and the ordinate, the observed 5-day mean temperature anomaly.

The system proved to be 77 percent correct in separating the dry and moist periods. A skill score based on chance, using the actual marginal totals of forecast and observed data shows 0.53 [2].

When the prognostic 5-day mean 700-mb. height and height gradient data and the prognostic temperature anomalies for the same test period were used, the correct score was reduced to 67 percent and the skill score was reduced to 0.32 (table 1B). Similar computations were made using the prognostic material for the last 5 years of this same period, 1954 through 1958. These showed a correct score of 73 percent or a skill score of 0.42 (table 1C). This suggests that the skill in preparing the temperature anomalies has improved in recent years.

The above forecast system was tested during September 1959, which was not included in the original sample. The

TABLE 2.—*Verification of 5-day average 4 p.m. relative humidity forecasts for September 1959*

Forecast period 1959	Prognostic humidity class from fig. 3	Prognostic temperature anomaly	Objective relative humidity forecast from fig. 4	Observed mean relative humidity (percent)	Verification of objective forecast	Subjective forecast in terms of chance of strong east winds (percent)	Verification of subjective forecast
9/1-5	C	N	Moist	57	+	20	+
9/3-7	C	A-N	Moist	69	+	40	+
9/5-9	E	N-B	Moist	55	+	10	+
9/8-12	B	B	Moist	41	+	30	+
9/10-14	D	B	Moist	47	+	20	+
9/12-16	E	A-N	Moist	54	+	30	+
9/15-19	E	A-N	Moist	63	+	10	+
9/17-21	E	N-B	Moist	65	+	20	+
9/19-23	E	B	Moist	61	+	20	+
9/22-26	D	B	Moist	61	+	70	-
9/24-28	C	A	Dry	61	-	60	-
9/26-30	C	B	Moist	51	+	30	+
9/29-10/3	A	B	Moist	45	+	80	-

basic forecasts are in terms of dry and moist 5-day periods. As before, average 5-day relative humidities at the three selected stations of less than 40 percent verified the dry forecasts and 40 percent or greater the moist forecasts. However, it was pointed out earlier in the article that low relative humidities in northwestern Oregon during September almost invariably coincide with periods of strong east winds across the Cascades. Thus, the dry forecasts can be interpreted as periods with better than 50 percent chance of strong east winds and the moist forecasts as periods with less than 50 percent chance of strong east winds.

Before being issued as operational forecasts, the objective forecasts in some cases were altered subjectively by the fire-weather forecaster. Also the final forecasts were issued in terms of the probabilities of strong east winds. In two cases, when the objective method called for moist conditions, more recent data from the eastern Pacific appeared to increase the chance of east winds, and the objective forecast was changed subjectively to indicate a greater than 50 percent chance of dry, east winds. In both cases, the objective prediction proved to be accurate and the east winds or low relative humidities did not develop.

The thirteen 5-day forecast periods which fell, all or in part, in September were considered in the verification (see table 2). Of the 13 subjective forecasts issued, low relative humidities (or greater than 50 percent chance of strong east winds) were forecast 3 times and high relative humidities (or less than 50 percent chance of strong east winds) were forecast 10 times. The month of September 1959 was quite unusual in that there were no low relative humidity or strong east wind conditions. Thus, the forecasts verified 10 out of 13 times.

It is interesting to note that the objective forecast would have resulted in 12 correct forecasts out of 13 cases. Statistically, neither result can, of course, be considered as showing any real basis for forecasting skill because (a) no strong east wind or low relative humidity periods were observed and (b) the number of forecasts is too small.

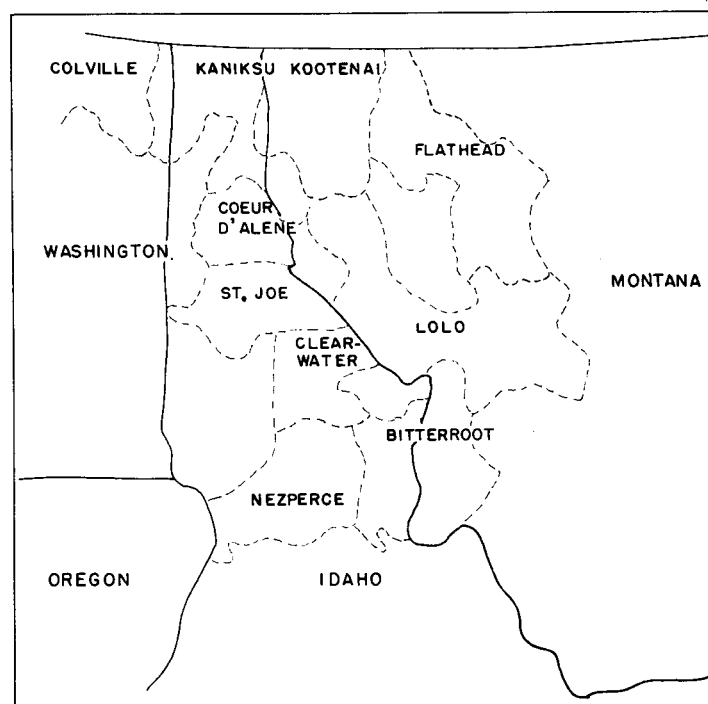


FIGURE 5.—The ten National Forests in the western portion of U.S. Forest Service Region 1.

It is believed that extended forecasts of periods of warm dry weather and continental winds, such as the east winds in Oregon and Washington, the Santa Anas in southern California, the "monos" in northern and central California, and northwesterly winds in southeastern United States, are feasible and can be related to the development of a persistent and intense upper ridge on the 5-day mean charts. This piling up of warm dry air probably takes place immediately upstream from the forecast area. Much work will have to be done in determining the proper parameters to be used in each of these cases.

3. THUNDERSTORM OCCURRENCES IN NORTHERN ROCKY MOUNTAINS

In the northern Rocky Mountains, thunderstorms and lightning fires create a major forest fire hazard. These storms occur during July and August when the fuels are either dry or are drying out rapidly. Many of these thunderstorms have little or no precipitation reaching the ground. Over 70 percent of all the fires in Forest Service Region 1, comprising Montana, northern Idaho, and extreme northeastern Washington, are caused by lightning. During one extreme 10-day period in 1940, 1,488 lightning fires were started. It is essential from a fire control standpoint to anticipate this lightning fire hazard. Considerable success has been achieved in the 24- to 48-hour forecasts, but little attention has been given to the forecasting of thunderstorms on a 5-day basis.

The purpose of this part of the study is to correlate certain meteorological variables which appear on the 5-day mean charts with thunderstorm occurrences in the

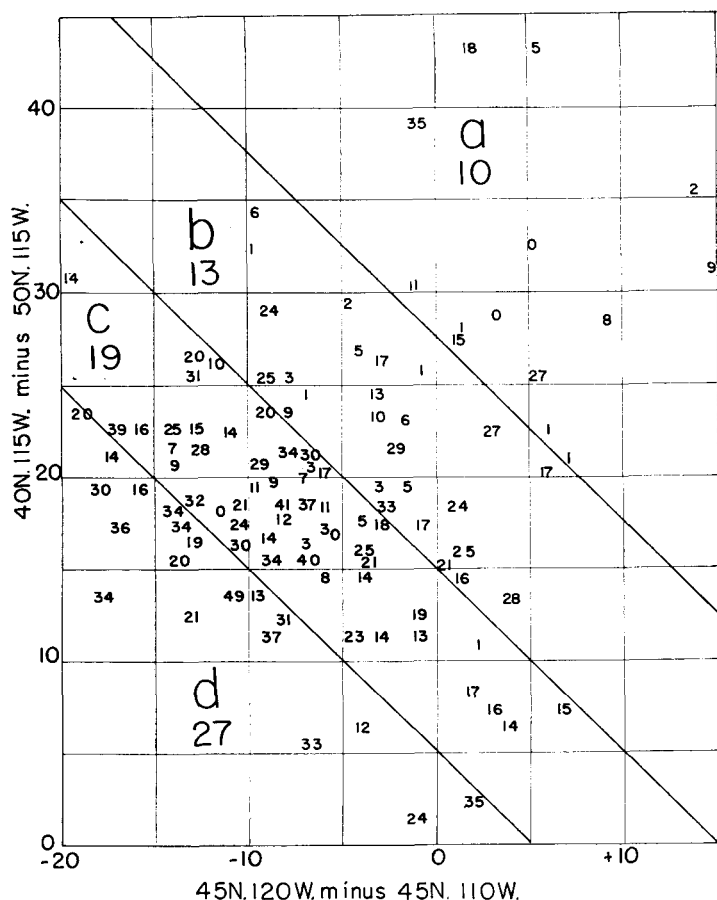


FIGURE 6.—Scatter diagram for National Forest-thunderstorm days using the 5-day mean 700-mb. west-east and north-south height gradients as the parameters.

northern Rocky Mountains. In the 10 National Forests in the western portion of Forest Service Region 1, shown by figure 5, the occurrence of thunderstorms by National Forests was tabulated for the 5-day periods coinciding with those used by the Extended Forecast Section. This included 112 periods, mostly in July and August, from 1954 through 1958. If a thunderstorm was reported anywhere in a National Forest, this was listed as a thunderstorm day for that Forest. Thus over any 5-day period, the number of National Forest-thunderstorm days could vary from 0 to 50.

After a careful inspection of the observed 5-day mean departure from normal charts and the observed 5-day mean circulation patterns at both the surface and 700-mb. levels, several parameters were tried in an effort to find some correlation with the observed number of National Forest-thunderstorm days. The 700-mb. heights at various significant points in the immediate or adjacent areas, the vorticity over the area as determined from the 700-mb. height data, and various height gradients were tried.

The most useful parameters proved to be the west-east (45° N., 120° W.– 45° N., 110° W.) and the south-north (40° N., 115° W.– 50° N., 115° W.) height gradients on the observed 700-mb. 5-day mean charts. This is reason-

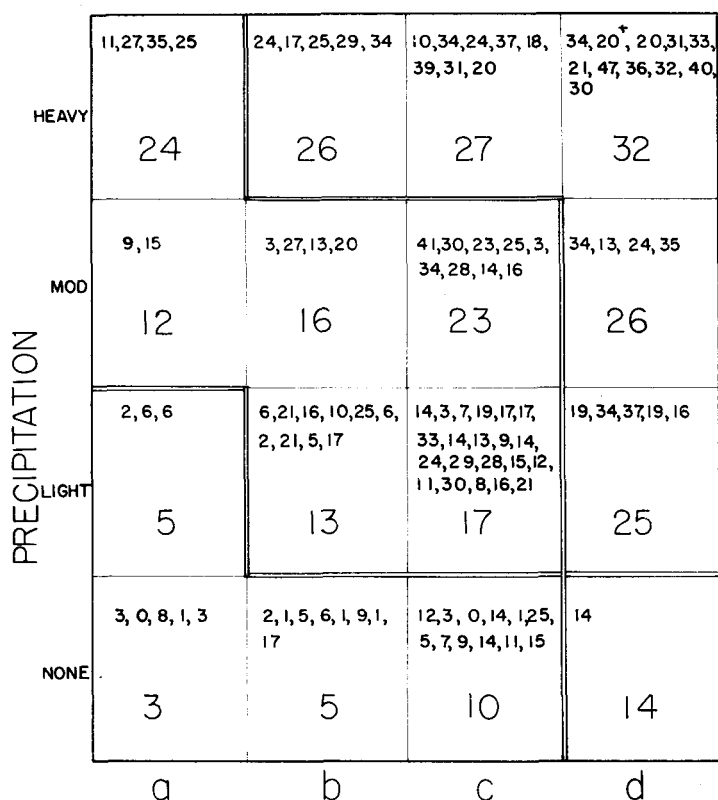


FIGURE 7.—Scatter diagram for National Forest-thunderstorm days. Abscissas are the estimated classes from figure 6 and the ordinates are the 5-day observed precipitation anomalies.

able since flow from the southerly quadrant should be more effective in bringing in the necessary moisture for thunderstorm initiation than flow from the northwest or north.

A scatter diagram (fig. 6) was constructed using the west-east and south-north height gradients as the predictors with the actual number of National Forest-thunderstorm days plotted at each point. While there is considerable scatter in the number of thunderstorm days within each division, it was possible to stratify the data into four classes, a, b, c, and d, with averages of 10, 13, 19, and 27 National Forest-thunderstorm days respectively in each class.

Additional parameters were sought, including 5-day temperature and precipitation anomalies. There proved to be little correlation with the temperature anomalies, but the precipitation anomalies were well correlated with the number of thunderstorm days. While precipitation is in a degree dependent on the circulation patterns, it is also dependent on other meteorological processes, such as vertical motions and availability of moisture.

The final scatter diagram (fig. 7) was constructed by using the class intervals obtained from figure 6 and the observed precipitation anomalies as the predictors. Four classes were used in the precipitation anomaly data: I. None; II. None to light and light; III. Light to moderate and moderate; IV. Moderate to heavy and heavy. The intermediate classes were necessary because

of the occurrence of more than one class in the forecast area. The results are shown in figure 7 with the average number of National Forest-thunderstorm days shown in each of the 16 squares.

In order to test the above relationship, the National Forest-thunderstorm days were divided into the following classes: I. None to a few (10 or less days); II. Scattered thunderstorms over area (11 to 24); III. Widespread thunderstorms over area (25 or more).

Using the entire developmental data for the 112 5-day periods from 1954 through 1958, covering the months of July and August and extending a few days into September, the contingency table in table 3A was obtained. The 66 correct class forecasts gave a score of 59 percent correct; the skill score over chance was 0.38.

The next step was to use the prognostic 5-day 700-mb. charts and the prognostic precipitation anomalies. A new contingency table (table 3B) for the same period from 1954 through 1958 was obtained. The number of correct class forecasts was now reduced to 56, a score of 50 percent correct; the skill score over chance was 0.24.

The above system was tried out during the 1959 fire season, which was not included in the developmental sample. Of the 25 5-day periods between July 11 and September 5, the correct class was forecast 16 times and misses occurred on 9 times (see table 4). However, this may not be a fair test since the period from July 11 through the first half of August was quite dry with very few thunderstorms.

It should be pointed out that these forecasts give the total number of expected thunderstorm days by National Forests over the 5-day period and not the distribution of the storms during the period. It must also be realized that in any given 5-day period an excessive number of

TABLE 3.—National Forest-thunderstorm days over 5-day periods for July and August

A. Using 5-day mean observed charts for 1954-58

		Observed			
		10 or less	11 to 24	25 and over	Total
Expected	10 or less	21	6	1	28
	11 to 24	12	25	14	51
	25 or over	1	12	20	33
	Total	34	43	35	66/112

Percent correct = 59 Skill score over chance = 0.38

B. Using 5-day mean prognostic charts for 1954-58.

		Observed			
		10 or less	11 to 24	25 or over	Total
Forecast	10 or less	18	10	15	43
	11 to 24	13	26	9	48
	25 or over	1	8	12	21
	Total	32	44	36	56/112

Percent correct = 50 Skill score over chance = 0.24

TABLE 4.—Verification of National Forest-thunderstorm day forecasts by 5-day periods during July and August 1959. (I=10 or less, II=11-24, III=25 or more)

Date	Class from fig. 6	Prognostic precipitation anomaly	Objective class forecast from fig. 7	Observed thunderstorm days	Observed Class
7/7-11	a	O-L	I	<10	I
9-13	c	O	I	3	I
11-15	c	O	I	3	I
14-18	b	O	I	0	I
16-20	c	O	I	2	I
18-22	c	O	I	2	I
21-25	b	O	I	5	I
23-27	b	O	I	12	II
25-29	c	O	I	8	I
28-8/1	b	O	I	14	II
30-8/3	a	O	I	13	II
8/1-5	c	O	I	8	I
4-8	b	L-M	II	1	I
6-10	b	O	I	0	I
8-12	b	O	I	8	I
11-15	a	M	II	8	I
13-17	a	M	II	0	I
15-19	b	M	II	9	I
18-22	a	M-II	II	27	III
20-24	b	M-II	III	26	III
22-26	c	M	II	13	II
25-29	b	L	II	14	II
27-31	a	M-II	II	17	II
29-9/2	b	H	III	5	I
9/1-5	a	O	I	3	I

16 Correct 9 Wrong

lightning fires might result from only a few scattered thunderstorms, which would only show as a period with a low total number of National Forest-thunderstorm days. This was well illustrated by the July 31 to August 1, 1959 storm. Only six National Forests reported thunderstorms on July 31 and seven on August 1 with no other activity within the 5-day period. Thus, this period shows a total of only 13 National Forest-thunderstorm days for the 5-day period even though a very large number of lightning-caused fires resulted from these storms. These storms were accompanied by little or no precipitation and the ground fuels were critically dry when the storms occurred.

This present study does not directly differentiate between thunderstorms with heavy precipitation and thunderstorms with little or no precipitation. This should be investigated more carefully in future studies.

However, it is felt that this type of extended forecast has considerable value to fire control operations. As the techniques and accuracy of the 5-day forecasts improve and further interpretative studies are made, this tool can serve as a working basis for the planning for the next 5 days. Since the 5-day forecasts are issued three times each week, major reappraisals can be made when it becomes apparent that the previous forecasts are incorrect. It is urged that similar work be done for thunderstorms in other areas.

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